ASSESSMENT OF PERSONAL EXPOSURES TO ENVIRONMENTAL TOBACCO SMOKE IN BRITISH NON SMOKERS

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ABSTRACT

Environmental Tobacco Smoke (ETS) exposure of 255 non-smoking subjects was assessed by several methods. Each subject wore a personal air sampler for 24 hours, answered a questionnaire about air quality and ETS exposure, and provided saliva samples for cotinine analysis before and after the monitoring period. The study was conducted in the Leeds and Harrogate areas of northern England.

Median exposure to ETS particles was below the detection limit of 4 $\mu g\ m^{-3}$. Median exposure to nicotine was 0.5 $\mu g\ m^{-3}$ and median saliva cotinine levels were 0.7 $ng\ mL^{-1}$ and 0.6 $ng\ mL^{-1}$ for the pre and post-cotinine samples. Median exposure to particles from all sources was 142 $\mu g\ m^{-3}$. Approximately 80% of subjects assessed their ETS exposure as 'none' or 'low'.

On average, the home made the greatest contribution to ETS exposure, followed by leisure, and then work. Travel was a minor contributor to exposure.

Overall, subjects with a partner who smokes were exposed to more ETS than subjects with no partner or a non-smoking partner. However there was considerable overlap in the exposures of individuals within these groups.

Where subjects assessed their ETS exposure as 'none' or 'low', this was in general supported by the direct measurements of exposure. However, for exposure assessed as 'moderate' or 'high' there was a wide range in the corresponding direct measurements.

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There was a moderate correlation between exposure to nicotine and exposure to ETS particles (R^2=0.66), but poor correlation between nicotine exposure and saliva cotinine levels (R^2=0.07 for pre and R^2=0.13 for post-cotinine samples)

Overall, ETS made only a small (median 2.5%) contribution to particles from all sources as collected by the personal monitor. Exposure to ETS particles did not correlate (R^2=0.04) with exposure to particles from all sources.

Out of 327 volunteers recruited as non-smokers for this study, 53 (16%) were identified as likely smokers by saliva cotinine levels or detailed questioning.

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INTRODUCTION

Two main approaches have been used in the past to assess whether there is any risk associated with exposure to ETS. One is based on epidemiology and the other based on the quantities of smoke constituents to which non-smokers are exposed.

A criticism of published epidemiological studies of ETS is that almost all failed to include a direct measurement of exposure level (Coultas et al. 1989). Although spousal smoking has frequently been used as an index of exposure in these studies, the accuracy of this approach has been questioned (Koo et al. 1987). Therefore, it is important to determine how well reported spousal smoking correlates with directly measured exposure. It is also important to determine how well ETS exposure can be predicted by questionnaire or by measurements of saliva cotinine since these approaches are also used as an alternative to direct measurements of exposure. In the case of cotinine measurements consideration must be given to threshold levels (Etzel 1990) in order to exclude smokers from ETS exposure evaluation. There have been various ideas on what defines a regular smoker. The EPA for example defined regular smokers as those having more than 30% of the average cotinine level found for smokers.

Most of the information about the quantities of smoke constituents to which non-smokers may be exposed is based on fixed-site measurements of ETS levels in locations such as homes, offices and restaurants together with assumptions about the time people are thought to spend in these locations. There have been numerous such studies (reviewed by

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Guerin et al. 1992) particularly in the USA, but these do not characterise properly the range of ETS exposure experienced by non-smokers over a period of time.

There have, until recently, been few attempts to measure directly the exposure of people as they go about their normal lives, even though this approach should provide more realistic results than those calculated from ETS levels in locations. The use of personal monitoring has been common practice in the industrial hygiene field for many years, but it is only recently that the analytical methodology has been refined sufficiently to allow ETS measurements to be carried out by this approach. When personal monitoring is used subjects can be monitored over set periods, such as 24 hours or longer. It could be assumed that the monitoring period is typical of a subject's normal exposure but it is preferable to establish that this is the case by questionnaire.

The levels of both nicotine and ETS particles have been determined in several studies of locations, but personal monitoring studies have tended to measure nicotine and not particles. In view of the limitations of nicotine as a marker for ETS (Guerin et al. 1992), there clearly is a need for personal monitoring studies in which nicotine and ETS particles are measured simultaneously. It is now possible to estimate the ETS contribution to particles from all sources (PAS) by a number of methods. Measurements using ultra violet light (UVPM) and fluorescence (FPM) and the determination of solanesol (SolPM) are all used in this study.

UVPM measurements and, to a lesser extent FPM measurements, are believed to overestimate ETS contributions to total particles because of the presence of interfering

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compounds. Solanesol is a constituent of Tobacco and other members of the Solanacae family, e.g potatoes. It is found in the particulate phase of ETS and its presence in air is likely to be derived only from tobacco smoke and would not be expected to overestimate ETS particles.

In this study, the 24-hour exposure to ETS of a group of UK non-smokers was assessed by personal monitoring. Subjects were asked detailed questions about their smoking history and exposure to ETS, and saliva samples were taken for cotinine measurements. Subjects were asked to assess their overall exposure to ETS. These assessments could then be compared to measurements made directly using the monitor. Relative contributions from the home, work, leisure and travel to overall ETS exposure were assessed by direct measurements in conjunction with questionnaire information. In addition, spousal smoking, questionnaires and saliva cotinine levels were compared with personal monitoring as methods of assessing ETS exposure. Comparison of the methods of assessing ETS exposure was also made in order to determine the extent of any correlation. The weather conditions were also monitored and recorded throughout the study period.

Some researchers refer to 'cigarette equivalents' when assessing the risk of ETS exposure to non smokers. However, mainstream smoke (that inhaled) is not chemically identical to ETS smoke or exhaled smoke. Comparison of the quantities of ETS exposure with cigarette yields has been made in this study, but only to allow the magnitude of the exposure to be put into perspective.

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Misclassification occurs in ETS studies when smokers report themselves to be non-smokers or vice versa. In this study subjects were regarded as misclassified and they were excluded from ETS exposure evaluation on the basis of their saliva cotinine levels. The rejection criteria used were based on published saliva cotinine levels for smokers and non-smokers (Etzel 1990).

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METHODS

Recruitment of subjects

Potential subjects for use in this study were randomly selected from an existing data base of 15,000 volunteers held at Besselaar Clinical Research Unit, Leeds, England. They were contacted by letter and asked to take part in a general air quality study. Those who volunteered had to complete a recruitment questionnaire which included a question about their smoking status. Only those volunteers who confirmed that they were non-smokers were considered, from which 327 were used on this study.

To avoid the possibility of influencing their behaviour, subjects were told that the purpose of the study was to assess Air Quality and were not informed that it was related to ETS exposure.

The Monitoring Session

The personal monitors were delivered by an investigator (a member of Hazleton Europe's scientific staff) to each subject on the appointment date, and the use of the pump and the wearing of the monitor was explained. The subjects were asked to wear the monitor at all times throughout the 24 hour test period except when in bed or bathing/showering, when they were asked to place the monitor nearby in a vertical position. Each subject was asked to complete an activity diary over the 24 hour period and to record observations of general air quality including the presence of tobacco smoke.

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At the start of the session the caps were removed from the personal monitor and the pump stroke counts recorded. The pump was switched on by the investigator, and a saliva sample (pre-sample) taken.

After 24 hours the pump was switched off and the pump stroke counts recorded. A comprehensive questionnaire was completed by the investigator, with the subject referring to the diary as necessary. Finally, a saliva sample (post-sample) was taken.

The pump stroke counts were used to confirm that the pump had operated continuously. The pump flow rate was measured before and after each monitoring session.

Collection of Saliva Samples

Dental swabs sealed in hygienic vials (salivettes. Sarstedt, Leicester, England), were used to collect saliva samples. By removing the lid and tilting the vial to the lips, the subject could transfer the swab to the mouth without touching it. After chewing for a timed 1.5 minutes, the swab was returned to the vial using the tongue. The cap was then replaced and the vial stored in a freezer (-20°C) until required for analysis.

The Personal Monitor

The purpose of the personal monitor was to collect ETS particles and nicotine from the air close to the subject's breathing zone throughout a 24 hour period. The monitor consisted of an aluminium filter holder (Figure 1) which rested in the centre of the

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subject's chest, supported by a rigid wire necklace. The filter holder was connected to a battery-operated pump (Model 222-3, SKC Ltd., Dorset, England) by flexible plastic tubing. The pump was concealed in a small, padded bag, attached to a belt around the subject's waist and was almost inaudible when operating within this bag.

The aluminium filter holder contained two filters in series: a Teflon front filter (FALP 02500, Millipore UK Ltd., Hertfordshire, England) and a second filter (Fiberfilm T60A20, Pallflex Corp., Connecticut, USA) acidified with sodium bisulphate. The front filter was shown to collect all ETS particles and the acidified filter was shown to retain nicotine very efficiently. The front filter was sandwiched between a stainless steel sealing ring and a stainless steel supporting grid. In prototype designs Teflon seals and spacers were used but this resulted in weight changes in the front filter of several micrograms. The use of stainless steel rings and supporting grids eliminated this weight change. The acidified filter was sandwiched between Teflon spacers and this eliminated losses of nicotine within the filter holder.

The pump flowrate was set to 139 mL min^{-1}, giving a total air sample of 200 litres in the 24-hour sampling period. At this flow rate, and with a fully-charged battery, a pump would run for about 30 hours when attached to the filter holder.

The filter holder was fitted with a security tag which ensured that the subject could not dismantle the holder without detection. Sealing caps were used to exclude air from the filter holder before and after the sampling period.

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ANALYTICAL PROCEDURES

Particles from all sources

Particles from all sources were trapped on the Teflon front filter in the personal monitor. The weight collected was determined to the nearest microgram by weighing the filter before and after the monitoring period. These weighings could be carried out with good precision providing that static charge was eliminated from the filters prior to weighing. This was achieved using a commercially available, radioactive, static eliminator (PDV-1 Amersham International plc, England).

Experiments in a Model Room demonstrated that the collection efficiency for ETS particles using a personal monitor at a flow rate of 139 mL min^{-1} was equivalent to that of commercially available filter holders at the 'standard' flow rate of 2 L min^{-1}. This result is to be expected for small (< 1 μm) particles such as those present in ETS. Calculations using the sampling rate and orifice dimensions of the personal monitor indicate that the particle collection efficiency would decrease with particle size, approaching zero efficiency at about 50 μm diameter.

Particle concentrations measured by the personal monitor do not correspond to either Total Suspended Particles (TSP) or Respirable Suspended Particles (RSP) but will fall somewhere between these values. In this publication, the term PAS is used to refer to Particles from All Sources as collected by the personal monitor. Since, in most

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situations, RSP is a major fraction of TSP (Monn et al. 1993), the PAS results in this study would be expected to be similar to RSP for most subjects.

Estimation of the ETS contribution to particles from all sources

UV, fluorescence and solanesol measurements were used to estimate the ETS contribution to the total quantity of particles collected by the front filter of the personal monitor. The use of these three methods has been discussed by Ogden et al. (1990).

For the UV and fluorescence measurements, the particles were extracted from the Teflon front filter with methanol. An aliquot of the extract was injected into a column-less high performance liquid chromatography (HPLC) system and passed through a UV detector (325 nm) and a fluorescence detector (excitation 300 nm, emission 420 nm) in series. The peak areas of the UV and fluorescence signals obtained were used to calculate the quantity of ETS particles in the extract using predetermined conversion factors.

The solanesol content of the methanol extract was determined by reverse phase HPLC using methanol as the mobile phase and UV detection at 210 nm. The quantity of solanesol in the extract was converted to a quantity of ETS particles using a predetermined factor.

The factors used to convert UV, fluorescence and solanesol measurements into weights of ETS particles were established by experiments in a Model Room. ETS was generated by humans smoking combinations of typical UK cigarettes (five best-selling brands) and

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ETS particles were collected from the Model Room atmosphere using the personal monitors. A range of ETS particle weights were collected on personal monitor filters by varying the sampling time. The UV absorption, fluorescence and solanesol content were measured and the relationship with weight of particles determined.

After the initial calibration against ETS, UV measurements were calibrated against a surrogate standard of 2,2',4.4'-tetrahydroxybenzophenone (THBP) and fluorescence measurements were calibrated against scopoletin as a surrogate standard. These surrogate standards were used for calibration purposes throughout the study.

The relationships obtained were reasonably consistent with those reported by Ogden et al. (1990) for US cigarettes (Table 1).

The ETS particles determined by the UV and fluorescence methods are commonly referred to as UVPM and FPM respectively. ETS particles determined by the solanesol method are referred to as SolPM in this paper.

Nicotine

Extracts of the front and back filters were basified with sodium hydroxide. Nicotine was extracted into di-isopropyl ether containing N-ethylnornicotine as an internal standard and triethylamine to prevent adsorption of nicotine by glassware. Nicotine was measured by megabore capillary GC with nitrogen-selective detection. It was shown by parallel sampling experiments that results for nicotine obtained using the personal monitor were

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equivalent to those where nicotine was collected on sorbent tubes containing XAD-4 resin, as used by Ogden et al. (1989).

Saliva Cotinine

The salivette containing the saliva sample was thawed and then centrifuged to release the saliva from the cotton swab. N-Ethylnorcotinine was added to a 0.5 mL aliquot of the saliva sample as an internal standard. The aliquot was made basic with ammonium hydroxide and then cotinine and the internal standard were extracted into dichloromethane and analysed by capillary GCMS in the ion monitoring mode. Mass 176 was used to detect cotinine and mass 190 to detect the internal standard. Mass 98 and mass 112 were used as confirmatory ions for cotinine and N-ethylnorcotinine, respectively.

Mass spectrometry was used because preliminary tests had shown that nitrogen-selective detection lacked adequate selectivity at low cotinine levels. There were several nitrogen-containing compounds at similar retention times to cotinine in some saliva samples and this made it difficult to confirm the presence or absence of cotinine.

Detection limits

Detection limits for the analytical methods are listed in Table 2. For each sampling day one 'blank' personal monitor was assembled and dismantled at the same times as the subjects' personal monitors. Filters from the blank personal monitor were analysed in the same way as those from the used monitors.

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Limits of detection were established by taking account of results from the blanks together with the signal to noise ratio on the real samples and the calibration standards. A signal to noise ratio of three was required for a positive signal. Results for the blank monitors were not subtracted from the results for the subjects' monitors.

The front filter used for measuring PAS was weighed as a blank throughout the study. These weighings indicate the weight change was rarely more than 1 μg. On this basis, a weight change of 4 μg was considered real and measurable for a subject's filter. This corresponds to 4 μg in the 200 litres of air collected or 20 μg m^{-3} of PAS. In practice PAS results were not below this detection limit for any subject.

For many of the analyses, the levels found were below the limit of detection. This raises the question of how to deal with these results in the calculation of means, medians etc in the data analyses. If a value of zero was applied when results are below the limit of detection then this would lead to an underestimate of average exposure. Conversely, if the value of the detection limit itself was applied in such cases then the average exposure would be overestimated. As a reasonable compromise, a value which is one half of the detection limit was used for the data analysis. The same compromise has been used in other studies of this type, e.g Kirk et al. 1988, and Nehls et al. 1973.

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RESULTS AND DISCUSSION

Subjects Studied

From the 327 volunteers recruited for the study, 72 were excluded for various reasons which included 7 who admitted smoking during the monitoring period. For the remaining 255 subjects, the age and sex distribution is listed in Table 3.

Excluded Subjects

Subjects and their corresponding analytical results were excluded from the study for various reasons. These are listed in Table 4.

It is debatable when using saliva cotinine levels what cut-off point should be used when attempting to distinguish between smokers and non-smokers. In a review of saliva cotinine levels, Etzel (1990) reported that non-smokers usually have levels below 5 ng mL^{-1} but that heavy exposure can result in levels around 10 ng mL^{-1}. In this study, a higher threshold of 25 ng mL^{-1} was chosen since this would avoid the possibility that some heavily exposed non-smokers might be incorrectly categorised as smokers.

The number of subjects in this study that would have been rejected as smokers at different threshold levels is given in Table 5; the seven subjects who admitted smoking are also included.

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These results show that, in this study, the choice of the saliva cotinine level used as a threshold was not critical, especially in the range 15 to 30 ng mL^{-1}.

It is of interest that a further 12 subjects admitted smoking between recruitment and the 24 hour monitoring period (but not during the monitoring period itself) and yet they were not identified as smokers by their saliva cotinine measurements. This demonstrates that saliva cotinine measurements can fail to identify occasional smokers who have not smoked for a few days and could thus underestimate the extent to which smokers describe themselves as non-smokers. It is possible that further subjects in this study were occasional smokers, or smokers of very low yielding cigarettes, and were not detected.

These findings demonstrate that it can be very difficult to determine whether a person really is a regular smoker, non-smoker or even a casual smoker. This clearly needs to be taken into account in other investigations of ETS exposure.

Misclassification of Smoking Status

It was not anticipated that misclassification would occur to a significant extent in this study since the subjects were members of a well-documented group used for medical trials, and all subjects completed a recruitment questionnaire confirming their non-smoking status. In view of the recruitment criteria, it was surprising that 7 subjects admitted smoking during the 24 hour monitoring period (questionnaire), 12 subjects admitted smoking since recruitment (questionnaire), and 34 subjects were rejected on the

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basis of their saliva cotinine measurement. Thus 53 subjects out of a total of 327 (ie 16%) were identified as likely smokers and some of these were clearly regular smokers.

It is conceivable that some of the 34 subjects identified as possible smokers by saliva cotinine levels were really users of nicotine gum or a nicotine patch. As misclassification was not expected to occur at a significant level in this study, the questionnaire did not address possible use by the subjects of gum or patches. However, none of these subjects mentioned the use of nicotine gum or a patch, even though questioned in detail about their smoking history. Furthermore, nicotine patches were not in common use at the time of the study.

After completion of the study, the 34 subjects were contacted by the Besselaar Clinic and asked whether they had ever used nicotine gum or a nicotine patch. From the 17 that replied 16 stated that they had used neither. This suggests that the use of nicotine gum or a nicotine patch was not likely to be a significant factor in the identification of these subjects as smokers.

The median level of saliva cotinine for self-reported smokers (or nicotine users) in the UK was reported (Lee 1987) to be 319 ng mL^{-1} for men and 311 ng mL^{-1} for women. Subjects in this study with saliva cotinines over 100 ng mL^{-1} could be regarded as regular smokers (based on an EPA definition, 1992) even though they had described themselves as non-smokers during recruitment.

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The number of subjects found to have saliva cotinine levels greater than 25 ng mL^{-1} and their ranges is shown in Table 6.

Those subjects with saliva cotinine levels between 25 and 100 ng mL^{-1} may be either occasional smokers or regular smokers who had refrained from smoking just prior to the test period. The misclassified subjects on this study are listed by age and sex in Table 7.

The occupations of the misclassified subjects included, for example, housewives, a nurse, a butcher, civil servants, a cytogeneticist, a greenkeeper, clerks, labourers, a joiner, VDU operators, a laboratory technician, a musician and unemployed people.

These results indicate that people from a wide variety of occupations mis-report their smoking status, and that misclassification may be more extensive among men (33 out of 150) than women (20 out of 176) in the UK.

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Relevance of 24-hour Samples

In order to assess whether the 24-hour sampling period was typical of normal ETS exposure, subjects were asked to compare their exposure during the sampling period with their average exposure over the last six months. The results are shown in Table 8.

Over 50% of subjects assessed their exposure in the monitoring period as typical of their average exposure during the last six months and less than 10% considered their exposure in the 24-hour period to be much less than normal. However, these results indicate that, on balance, the subjects judged their exposure to have been somewhat less than normal.

Objective evidence that the monitoring period was similar to recent exposure is that the mean, median and distribution of results for the pre-monitoring saliva cotinine levels are in close agreement with those of the post-monitoring values. Mean pre-cotinine and post-cotinine were both 1.4 ng mL^{-1} and the median pre and post-cotinine 0.7 and 0.6 ng mL^{-1} respectively.

The vast majority of subjects reported that wearing the personal monitor did not significantly interfere with their normal lifestyle.

Weather Conditions during the Study

The Study was conducted in October, November and early December, 1992. It was

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decided to avoid the summer months when ETS exposure was likely to be at a minimum and to avoid peak winter conditions when exposure would probably be at its highest and the practical difficulties of conducting the study at their greatest. The months chosen for the study were considered to be a good compromise.

There was a wide variation in weather conditions (as provided by the local weather centre) throughout the study. A summary is provided in Table 9.

There were three days on which hail and three days on which sleet were observed.

No obvious relationship could be seen between weather conditions and ETS exposure and there were no consistent trends when results were compared on a week-by-week basis.

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LEVELS OF EXPOSURE TO ETS FOR ALL SUBJECTS

Table 10 shows the summary analytical data for all subjects.

When reporting results, both the mean and the median values of data sets are quoted together with the range of values. In this type of study where the results are far from being normally distributed the median is a more appropriate measure than the mean. This is because one or two exceptionally high values can have a disproportionately large effect on the mean when most of the other values are relatively low.

Except in the case of PAS, the median exposure values reported in this table are close to, or below, the detection limits of the methods used. This is consistent with the subjective assessments in Figure 2, where it can be seen that about 80% of subjects considered that their ETS exposure was 'none' or 'low'.

Figures 3 and 4 show the distributions of SolPM, nicotine and saliva cotinine results. The distributions are very similar in each case and show that the exposure of most subjects is at the low end of the range. Over 70% of subjects were exposed to less than 10 $\mu g\ m^{-3}$ of ETS particles, over 60% were exposed to less than 1 $\mu g\ m^{-3}$ of nicotine and over 60% had saliva cotinine less than 1 $ng\ mL^{-1}$.

Results for the 10% of subjects with the highest measured ETS exposure, based on SolPM, are also shown in Table 10.

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In Table 10, the differences between the values for UVPM, FPM, and SolPM reflect the susceptibility of these measurements to interference. In some cases, FPM and especially UVPM, were observed at fairly high levels when there was no evidence of smoke exposure, clearly demonstrating the presence of interference. The solanesol-based measurements were more consistent with nicotine measurements and reported ETS exposure. For these reasons, discussion of ETS particle values in this paper relate to those estimated by the SolPM method.

Nicotine levels found in this study are in good agreement with those reported in other recent studies, including a study by Proctor et al. (1991) in which the nicotine exposure of women in Birmingham, England was measured by a personal monitoring technique. The saliva cotinine results are also very similar to those reported by Proctor et al. (1991). Table 11 compares these findings.

Ogden et all (1993), in a personal monitoring study of non-smoking women in the USA, reported median nicotine exposure of 0.43 $\mu g\ m^{-3}$ and median saliva cotinine of 0.8 $ng\ mL^{-1}$.

ETS particles were found to make only a small contribution to PAS (Table 12).

Assuming a breathing rate of 1 m^3 per hour, a person exposed to the median levels found in this study would be exposed to about 1,244 mg of PAS, 17.5 mg of ETS particles and about 4.4 mg of nicotine in a year. This calculation assumes these subjects are exposed at this 24 hour median level throughout the year.

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Based on the median levels for the tenth decile (SolPM), the most heavily exposed subjects would be exposed to approximately 1944 mg PAS, 561 mg of ETS particles, and 63 mg nicotine in a year. This calculation assumes these subjects are exposed at this higher 24 hour level throughout the year.

For comparison, a typical UK cigarette delivers about 12 mg of particles and 1 mg of nicotine to the smoker.

By modelling of fixed-site RSP measurements, Repace and Lowrey (1993) estimated typical daily non-smoker exposure in the USA, corresponding to 522 mg/year for ETS particles and 52 mg/year for nicotine. For the "most-exposed" non-smokers, their estimates correspond to an ETS particle exposure of 5220 mg/year and a nicotine exposure of 522 mg/year. The data reported here suggest that non-smoker exposure to ETS in the UK is well below that estimated by Repace and Lowrey for the USA.

Summary analytical results by age and sex are given in Tables 13 and 14. Male subjects were found to have higher average exposure to ETS particles and nicotine, and had higher saliva cotinine levels. The highest exposure for males and females was in the 21 to 29 age group.

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ETS EXPOSURE FROM WORK, HOME, LEISURE AND TRAVEL

Questionnaire data indicate that, on average, relative contributions to total ETS were subjectively ranked as Leisure > Work > Home > Travel, both during the monitoring period and during the last six months (Table 15).

Subjects with a non-smoking spouse/partner reported their primary source of ETS exposure as Leisure (48% of cases), Work (34% of cases), and Travel (3% of cases). However subjects with a smoking spouse/partner reported their main source of exposure as Leisure (19% of cases), Work (11% of cases), and Travel (0% of cases). The spouse was assessed as the primary source of exposure by 53% of these subjects.

Since subjects were not separately monitored at home, work, leisure or during travel it is not straightforward to assess the contribution of each of these sources to the 24 hour exposure. It is necessary to rely on information from the subjects about where they were exposed.

Most subjects either assessed their ETS exposure as 'none' or reported that their exposure was from more than one source. However, in those cases where the 24-hour result was attributed by the subject to a single source, the measured exposure levels, based on the means, suggest that the ranking is Home > Leisure > Work > Travel (Table 16).

In view of the small numbers of subjects having a single source of exposure, another approach was used to assess the home, work, leisure and travel contributions to total ETS

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exposure. For each subject exposed to more than 10μg m^{-3} of ETS particles, the assessment of percentage exposure from the four sources was used to distribute the corresponding measured 24-hour values between the four sources. Where the subjects assessed their 24 hour exposure as 'none', the corresponding measured values were distributed according to the number of hours the subject spent at each source.

The mean results computed using this method again suggest that the ranking is Home > Leisure > Work > Travel. These computed estimates are shown in Table 17.

The subjective and measured results both suggest that, overall, travel makes only a minor contribution to exposure.

It is interesting that the ranking of sources of exposure found by measurement is different from the ranking perceived by the subjects. One possible explanation for this is that subjects have based their judgements on the relative ETS levels in the four situations while taking insufficient account of the time spent in these situations.

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SPOUSAL SMOKING

In order to examine the effect of spousal smoking on ETS exposure, the subjects' results were divided into 3 groups depicted in Table 18.

Figure 5 shows the subjective assessments of ETS exposure made by the three groups. These subjective results indicate that the ranking of exposure is Smoking partner > No partner > Non-smoking partner, although there is considerable overlap between individual subjects within the groups. In the group with a smoking spouse/partner, 53% assessed their spouse/partner as their primary source of ETS exposure, 30% assessed work or leisure as their primary source of exposure, and 16% of subjects assessed their exposure as 'none'.

The measured exposure levels and the saliva cotinine data for these groups (Table 19) suggest the same overall ranking as the subjective data. The distribution of results for these groups (see Figure 6 for the distribution of ETS particles results) confirms that there is considerable overlap between the amount of exposure of individuals in these groups. Furthermore, 29% of subjects with a smoking partner were exposed to less than the mean ETS particle level of subjects with a non-smoking partner.

Figure 6 shows that 40% of subjects with a smoking spouse/partner have exposure in the lowest SolPM range. This is in agreement with the subjective exposure assessments of 'none' and 'low' chosen by 45% of subjects in this group.

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These findings indicate that a group of subjects with a smoking spouse/partner is likely to have a higher average ETS exposure than a group with a non-smoking spouse/partner. However, spousal smoking status clearly cannot be used, without supplementary evidence, to assess reliably the ETS exposure of individuals or small groups of subjects.

It can be seen from the median values in Table 19 that subjects with a smoking partner were exposed to about nine times more ETS particles and nicotine than subjects with a non-smoking partner. Corresponding data for women (Table 20) shows that the ETS particle exposure for those with a smoking partner was 5.5 times greater than for women with a non-smoking partner. The ratio was 6.5 for nicotine exposure and an average of 4.4 based on saliva cotinine. These ratios are higher than the ratio of 1.75 assumed for women in the USA by the EPA (1992) in their ETS risk assessment. A recent study carried out in the USA (Ogden et al. 1993) has also found these exposure ratios to be higher than 1.75.

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COMPARISON OF OTHER MEASURES OF SMOKE EXPOSURE

Subjective Assessments Compared with Direct Measurements

Figures 7 and 8 show the variation in measured exposure and saliva cotinine level for each grade of subjective exposure assessment. Although subjects were able to assess an exposure of 'none' or 'low' quite well, there was considerable variation in the direct measurements corresponding to the higher grades of subjective assessment. Some subjects who reported their exposure as 'high' had less directly measured exposure than other subjects who reported their exposure as 'low'.

Clearly, therefore, an individual's ETS exposure cannot be reliably assessed by a simple questionnaire. Better assessments may be possible by detailed questioning about the hours spent in various locations and the numbers of smokers present, but this was not examined in this study. Delfino et al. (1993) did investigate this issue and concluded that "the weak relationship between questionnaire estimates of ETS exposure and cotinine found in the present study, suggests that further investigation is needed to improve the assessment of recent ETS exposure".

Saliva Cotinine Compared with Direct Measurements

Saliva cotinine values showed poor correlation (R^2 = 0.06 for pre, R^2 = 0.14 for post) with 24-hour ETS particle exposure and, perhaps surprisingly, poor correlation with 24-hour nicotine exposure (R^2 = 0.07 for pre, R^2 = 0.13 for post). Some subjects exposed

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to relatively high levels of ETS particles and nicotine had no detectable saliva cotinine. Conversely, some subjects who had not been exposed to any measurable quantity of nicotine had relatively high levels of saliva cotinine. Possible reasons contributing to the lack of correlation could be:

(1) Different rates of nicotine metabolism between subjects.

(2) For many subjects, the saliva cotinine value was close to, or below, the limit of detection.

(3) ETS exposure occurring at different times within the 24-hour period for different subjects.

(4) The previous days' exposure determining the pre-cotinine level and the residual pre-cotinine contributing to the post-cotinine level.

(5) Dietary consumption of nicotine.

Poor correlations of nicotine exposure with saliva cotinine levels have also been found in other recent studies (Proctor et al. 1991) and therefore the value of saliva cotinine measurements for estimation of nicotine exposure at low levels must be seriously questioned.

Comparison of Methods for Estimating ETS Particles

Three methods were used in this study for estimating the ETS contribution to particles from all sources and it might be expected that there would be a good correlation between the results obtained. The relatively poor correlation between UVPM and

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SolPM (R^2=0.19) and the moderate correlation between FPM and SolPM (R^2=0.46) can be largely explained by interference in the UVPM and FPM measurements. In some cases where SolPM and nicotine are very low, i.e there was very little ETS exposure, there were relatively high levels of UVPM or FPM (Figure 9). Figure 10 shows that if these most obvious cases of interference were removed, there would be an improvement in the correlation between UVPM and SolPM and between FPM and SolPM. Also, the slopes of the lines of best fit would then approach, more closely, the expected value of 1.0.

Comparison of Nicotine and ETS Particle Exposures

ETS particles and nicotine are generated in a reasonably consistent ratio during smoking. However, nicotine is predominantly in the gas phase in ETS and is known to diffuse and decay more rapidly than ETS particles (Eatough et al. 1987). Furthermore, nicotine absorbs on walls, fabrics etc, and can be subsequently released into an atmosphere after ETS particles have disappeared. Therefore, at a given time, the ratio of nicotine to ETS particles may be quite different from the ratio in which they were generated (Nelson et al. 1992). However, in this study, a reasonably good correlation (R^2 = 0.66) was found between levels of nicotine and ETS particles. This was possibly because the sampling period was relatively long, thereby smoothing out shorter term fluctuations in the nicotine to ETS particles ratio.

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Comparison of Exposure to ETS Particles with Exposure to Particles from All Sources

There is no obvious reason why exposure to ETS particles should correlate with exposure to particles from other sources, and the total lack of correlation (R^2 = 0.04) found in this study is, therefore, not surprising. Clearly, measurements of particles from all sources, or Respirable Suspended Particles (RSP), should not be used to assess ETS exposure and it is essential to estimate the contribution ETS makes to total particles.

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CONCLUSIONS

The results of this study indicate that, for most subjects, exposure to nicotine and ETS particles was close to, or below, the limits of detection of the methods used. These low exposure levels are consistent with the corresponding assessments of exposure made by the subjects, and their saliva cotinine levels. The results are also consistent with other recent studies of ETS exposure by personal monitoring.

At the median level of ETS found in this study, a person would be exposed to approximately 1,244 mg of particles from all sources, 17.5 mg of ETS particles and 4.4 mg of nicotine in a year, assuming they were exposed at this 24 hour level throughout the year.

Based on the median levels for the tenth decile (SolPM), the most heavily exposed subjects would be exposed to approximately 1944 mg PAS, 561 mg of ETS particles, and 63 mg nicotine in a year. This calculation assumes these subjects are exposed at this higher 24 hour level throughout the year.

For comparison, a typical UK cigarette delivers about 12 mg of particles and 1 mg of nicotine to the smoker.

The above estimates of annual exposure to ETS are well below those obtained by Repace and Lowrey using a model based on fixed-site RSP measurements in the USA.

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Although subjects' assessments indicated that Leisure was the major source of ETS exposure, measurements by personal monitoring showed that, on average, the Home was the most important, followed by Leisure and Work. Travel was only a minor contributor to ETS exposure.

Subjects' assessments of their ETS exposure were not a reliable guide to their measured exposure except when their assessment was 'none' or 'low'. Individuals varied considerably in what they considered to be 'moderate' or 'high' levels of ETS exposure.

On average, subjects with a partner who smokes had about nine times greater exposure to nicotine and ETS particles than those with no partner or a non-smoking partner. However, there was considerable overlap in the exposure of individuals between these groups. For example, 29% of subjects with a smoking partner were exposed to less than the mean ETS particle level of subjects with a non-smoking partner. Clearly, spousal smoking status would not be a reliable means to assess the ETS exposure of individuals or small groups of subjects.

There was a moderate correlation between exposure to nicotine and exposure to ETS particles as measured by solanesol (SolPM). As might be expected, there was a very poor correlation between these components of ETS and exposure to particles from all sources. Overall, ETS made a small contribution (median 2.5%) to particle exposure and it is clear that exposure to particles from all sources cannot be used as a reliable measure of ETS exposure.

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There was a surprisingly poor correlation between ETS nicotine exposure and saliva cotinine level. However, other recent studies have drawn the same conclusion and further work should be undertaken to establish the reliability of saliva cotinine measurements as a means of assessing ETS exposure.

There was a greater than expected number of subjects (41) who had to be eliminated from the study for suspected smoking even though they were recruited as non-smokers. A saliva cotinine threshold of 25 ng mL^{-1} was used to distinguish between smokers and non-smokers. Results show that the threshold value used is not very critical, especially in the range 15 to 30 ng mL^{-1}.

Saliva cotinine measurements failed to identify a further 12 subjects who admitted occasional smoking since recruitment. It is, therefore, possible that other subjects who did not admit occasional smoking were also not identified. In total 53 subjects from an original 327 volunteers were identified as having smoked since recruitment, corresponding to a 16% misclassification rate. The rate was also significantly higher among men (22%) than women (11%).

Overall, this study has shown that it is feasible to assess exposure to nicotine and ETS particles by personal monitoring. This method of assessing ETS exposure would be expected to be more accurate than the saliva cotinine and questionnaire/lifestyle approaches that are sometimes used.

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Since the ETS exposure for most subjects was low and close to the detection limits of the methods used in this study, it would be advisable to improve the precision of measurements at the lowest levels by using a longer monitoring period in future studies.

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Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000

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Table 1

A COMPARISON OF THE QUANTITIES OF ETS PARTICLES WHICH CORRESPOND TO 1 μg OF EACH SURROGATE STANDARD AS DETERMINED IN THIS STUDY AND IN A STUDY BY OGDEN ET AL

	OGDEN et al.	This Study
1 μg THBP (used for UVPM)	8.0 μg ETS particles	6.1 μg ETS particles
1 μg scopoletin (used for FPM)	33.6 μg ETS particles	22.5 μg ETS particles
1 μg solanesol (used for SolPM)	30.0 μg ETS particles	38.5 μg ETS particles

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Table 2

DETECTION LIMITS OF THE ANALYTICAL METHODS USED

PAS	20 $\mu g\ m^{-3}$
UVPM	8 $\mu g\ m^{-3}$
FPM	4 $\mu g\ m^{-3}$
SolPM	4 $\mu g\ m^{-3}$
Nicotine	0.1 $\mu g\ m^{-3}$
Saliva cotinine	0.5 $ng\ mL^{-1}$

PAS = particles from all sources

UVPM = ETS particles measured by UV

FPM = ETS particles measured by Fluorescence

SolPM = ETS particles measured by Solanesol

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Table 3

AGE AND SEX DISTRIBUTION FOR STUDY SUBJECTS

Age range (Years)	Males	Females	Total
21 to 29	54	57	111
30 to 39	26	37	63
40 to 49	16	20	36
50 to 61	12	33	45
Total	108	147	255

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Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000

Table 4

EXCLUSION CRITERIA FOR STUDY SUBJECTS

Reason	Number
Subjects did not keep their appointment	5
The personal monitor pump failed to run for the full 24 hours	6
The analytical protocol was not properly followed	14
Smoke was deliberately blown into the monitor (Questionnaire)	6
Subjects admitted smoking during the 24 hour monitoring period (Questionnaire)	7
Subjects had a saliva cotinine level above the threshold for non-smokers	34
Total Excluded	72

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Table 5

NUMBERS OF SUBJECTS CLASSIFIED AS SMOKERS AS A FUNCTION OF SALIVA COTININE REJECTION THRESHOLD

Cut Off Level ($ng\ mL^{-1}$)	Subjects that would be rejected
10 (Etzel, 1990)	47
15 (McNeill, 1987)	41
25	41
30 (L ee, 1987)	37
50	34
100	22

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Table 6

DISTRIBUTION OF SALIVA COTININE LEVELS ABOVE 25ng mL^{-1}

Number of Subjects	Cotinine Range ($ng\ mL^{-1}$)
19	25 - 100
2	100 - 150
3	150 - 200
1	200 - 300
7	300 - 400
7	400 - 500
2	500 - 600

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Table 7

AGE AND SEX DISTRIBUTION OF MISCLASSIFIED SUBJECTS

Age range (Years)	Males	Females	Total
21 to 29	21	11	32
30 to 39	6	6	12
40 to 49	5	2	7
50 to 61	1	1	2
Total	33	20	53

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Table 8

A SUBJECTIVE COMPARISON OF ETS EXPOSURE IN THE MONITORING PERIOD AND IN THE 6 MONTHS PRIOR TO MONITORING

Subjective Assessment	Number of Subjects	% of Total
Much less than normal	25	9.8
Less than normal	91	35.7
Fairly typical of average exposure	131	51.4
More than normal	7	2.7
Much more than normal	1	0.4
Totals	255	100.0

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Table 9

WEATHER CONDITIONS DURING THE STUDY

Maximum Temperature	16.9°C	
Minimum Temperature	-3.2°C	
Maximum Humidity	96%	
Minimum Humidity	55%	
Maximum Daily Rainfall	10.4mm	
Maximum Daily Sunshine	7.5 hours	
Minimum Windspeed	2.1 ms^{-1}	(4 knots)
Maximum Windspeed	13.4 ms^{-1}	(26 knots)

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Table 10

SUMMARY STATISTICS FOR ALL ANALYTES AND ALL SUBJECTS

		Minimum	Maximum	Mean	Median	Number
PAS	($\mu g\ m^{-3}$)	20	1219	179	142	255
UVPM	($\mu g\ m^{-3}$)	4	299	31	21	255
FPM	($\mu g\ m^{-3}$)	2	146	16	10	255
SolPM	($\mu g\ m^{-3}$)	2	159	12	2	255
Nicotine	($\mu g\ m^{-3}$)	0.05	26	1.7	0.50	249
Pre-cotinine	($ng\ mL^{-1}$)	0.25	14	1.4	0.70	254
Post-cotinine	($ng\ mL^{-1}$)	0.25	12	1.4	0.60	248

SUMMARY STATISTICS FOR SUBJECTS WITH UPPER DECILE OF ETS EXPOSURE

		Minimum	Maximum	Mean	Median	Number
PAS	($\mu g\ m^{-3}$)	89	420	228	222	25
SolPM	($\mu g\ m^{-3}$)	42	159	72	64	25
Nicotine	($\mu g\ m^{-3}$)	0.44	26	8.4	7.2	25
Pre-cotinine	($ng\ mL^{-1}$)	0.25	8.4	2.3	1.5	25
Post-cotinine	($ng\ mL^{-1}$)	0.25	12	3.3	2.4	25

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Table 11

COMPARISON OF NICOTINE AND SALIVA COTININE LEVELS FOUND IN THIS STUDY WITH ANOTHER RECENT STUDY

Nicotine ($\mu g\ m^{-3}$)		Minimum	Maximum	Mean	Median
This Study		0.05	26	1.7	0.5
Proctor et al. (1991)		0	45	2.3	0
Saliva Cotinine ($ng\ mL^{-1}$)					
This Study	Pre Sample	0.25	14	1.4	0.7
This Study	Post Sample	0.25	12	1.4	0.6
Proctor et al. (1991)	Pre Sample	0.30	15	1.8	1.2
Proctor et al. (1991)	Post Sample	0	9	1.5	1.1

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Table 12

ETS PARTICLES (SolPM) AS A PERCENTAGE OF

PARTICLES FROM ALL SOURCES (PAS)

Minimum	0.2
Maximum	60.0
Mean	7.1
Median	2.5

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Table 13

SUMMARY STATISTICS OF DIRECTLY MEASURED ANALYTES FOR ALL SUBJECTS BY AGE AND SEX

Age range	Sex	Subjects	Minimum	Maximum	Mean	Median
			Nicotine ($\mu g\ m^{-3}$)			
All ages	Both	255	0.05	26	1.7	0.50
	M	108	0.05	26	2.2	0.87
	F	147	0.05	19	1.4	0.34
21-29	M	54	0.05	13	2.6	1.62
	F	57	0.05	15	1.5	0.47
30-39	M	26	0.05	26	2.0	0.40
	F	37	0.05	6	1.3	0.23
40-49	M	16	0.05	11	1.6	0.33
	F	20	0.05	19	1.6	0.31
50-61	M	12	0.05	9	1.9	0.69
	F	33	0.05	18	1.2	0.31
			Pre-Cotinine ($ng\ mL^{-1}$)			
All ages	Both	255	0.25	14	1.4	0.7
	M	108	0.25	14	1.9	1.0
	F	147	0.25	13	1.0	0.6
21-29	M	54	0.25	14	2.3	1.4
	F	57	0.25	8.2	1.1	0.7
30-39	M	26	0.25	13	2.0	0.9
	F	37	0.25	13	1.4	0.3
40-49	M	16	0.25	3.4	0.9	0.5
	F	20	0.25	2.6	0.7	0.7
50-61	M	12	0.25	4.4	1.0	0.4
	F	33	0.25	4.2	0.7	0.3
			Post-Cotinine ($ng\ mL^{-1}$)			
All ages	Both	255	0.25	12	1.4	0.6
	M	108	0.25	12	2.0	0.7
	F	147	0.25	8.1	1.0	0.25
21-29	M	54	0.25	12	2.3	1.3
	F	57	0.25	7.5	1.2	0.7
30-39	M	26	0.25	12	2.4	0.8
	F	37	0.25	7.0	0.9	0.25
40-49	M	16	0.25	7.8	1.4	0.25
	F	20	0.25	2.4	0.7	0.25
50-61	M	12	0.25	2.8	0.8	0.4
	F	33	0.25	8.1	0.9	0.25

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Table 14

SUMMARY STATISTICS OF DIRECTLY MEASURED ANALYTES FOR ALL SUBJECTS BY AGE AND SEX

Age range	Sex	Subjects	Minimum	Maximum	Mean	Median
				PAS ($\mu g\ m^{-3}$)		
All ages	Both	255	20	1219	179	142
	M	108	20	1219	169	136
	F	147	30	847	187	151
21-29	M	54	45	995	163	129
	F	57	35	420	171	150
30-39	M	26	48	1219	177	126
	F	37	52	539	208	190
40-49	M	16	20	524	181	152
	F	20	45	847	205	144
50-61	M	12	29	286	158	155
	F	33	30	549	183	131
				SolPM ($\mu g\ m^{-3}$)		
All ages	Both	255	2	159	12	2
	M	108	2	159	15	4
	F	147	2	153	11	2
21-29	M	54	2	97	17	6
	F	57	2	153	15	2
30-39	M	26	2	159	15	2
	F	37	2	88	10	2
40-49	M	16	2	51	9	2
	F	20	2	78	9	2
50-61	M	12	2	50	13	7
	F	33	2	87	5	2

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Table 15

SUBJECTIVE ASSESSMENT OF RELATIVE CONTRIBUTIONS TO ETS EXPOSURE DURING THE MONITORING PERIOD AND THE PREVIOUS 6 MONTHS

	Percent Relative Contributions	
	Monitoring Period	Last Six Months
Home	27.8	19.8
Work	31.5	29.4
Leisure	35.1	46.3
Travel	5.7	4.7

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Table 17

"COMPUTED" ESTIMATES OF EXPOSURE AT HOME, WORK, LEISURE AND TRAVEL FOR ALL SUBJECTS WITH TOTAL SolPM > 10 $\mu g\ m^{-3}$

	Minimum	Maximum	Mean	Median	Number
		SolPM ($\mu g\ m^{-3}$)			
Home	0	107	18	7.2	67
Work	0	79	8.0	0	67
Leisure	0	151	12	0.2	67
Travel	0	11	1.2	0	67
Overall	10	159	39	26	67
		Nicotine ($\mu g\ m^{-3}$)			
Home	0	16	2.1	0.30	66
Work	0	9.7	1.0	0	66
Leisure	0	24	1.6	0.03	66
Travel	0	2.1	0.1	0	66
Overall	0.05	26	4.9	3.6	66

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Table 18

DISTRIBUTION OF SUBJECTS BY SMOKING STATUS OF SPOUSE OR PARTNER

	Number in Group
Subjects with no spouse or partner	74
Subjects with a non-smoking spouse or partner	133
Subjects with a smoking spouse or partner	48
Total all Categories	255

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Table 19

SUMMARY EXPOSURE MEASUREMENTS FOR ALL SUBJECTS

BY CLASSIFICATION OF SPOUSE OR PARTNER

	Minimum	Maximum	Mean	Median	Number
		PAS ($\mu g\ m^{-3}$)			
NS Partner	20	995	166	129	133
SM Partner	48	1219	219	161	48
No Partner	35	539	178	143	74
Overall	20	1219	179	142	255
		SolPM ($\mu g\ m^{-3}$)			
NS Partner	2	159	7	2	133
SM Partner	2	153	29	17	48
No Partner	2	97	12	2	74
Overall	2	159	12	2	255
		Nicotine ($\mu g\ m^{-3}$)			
NS Partner	0.05	26	1.1	0.28	130
SM Partner	0.05	18	4.0	2.5	47
No Partner	0.05	19	1.5	0.55	72
Overall	0.05	26	1.7	0.5	249
		Pre-Cotinine ($ng\ mL^{-1}$)			
NS Partner	0.25	8.2	0.83	0.25	132
SM Partner	0.25	13	2.3	1.4	48
No Partner	0.25	14	1.8	1.0	74
Overall	0.25	14	1.4	0.7	254
		Post-Cotinine ($ng\ mL^{-1}$)			
NS Partner	0.25	12	0.99	0.25	128
SM Partner	0.25	8.1	2.2	1.5	47
No Partner	0.25	12	1.7	0.6	73
Overall	0.25	12	1.4	0.6	248

NS = non-smoking spouse or partner

SM = smoking spouse or partner

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Table 20

SUMMARY EXPOSURE MEASUREMENTS FOR WOMEN BY CLASSIFICATION OF SPOUSE OR PARTNER

	Minimum	Maximum	Mean	Median	Number
PAS ($\mu g\ m^{-3}$)					
NS Partner	30	847	175	128	80
SM Partner	89	497	219	166	26
No Partner	35	539	192	153	41
SolPM ($\mu g\ m^{-3}$)					
NS Partner	2	87	5	2	80
SM Partner	2	153	28	11	26
No Partner	2	88	10	2	41
Nicotine ($\mu g\ m^{-3}$)					
NS Partner	0.05	11	0.81	0.23	78
SM Partner	0.05	19	3.4	1.5	26
No Partner	0.05	19	1.3	0.35	40
Pre-Cotinine ($ng\ mL^{-1}$)					
NS Partner	0.25	8.2	0.79	0.25	80
SM Partner	0.25	13	1.8	1.3	26
No Partner	0.25	8.4	1.0	0.70	41
Post-Cotinine ($ng\ mL^{-1}$)					
NS Partner	0.25	7.5	0.93	0.25	76
SM Partner	0.25	8.1	1.3	0.90	25
No Partner	0.25	7.0	0.92	0.25	41

NS = non-smoking spouse or partner

SM = smoking spouse or partner

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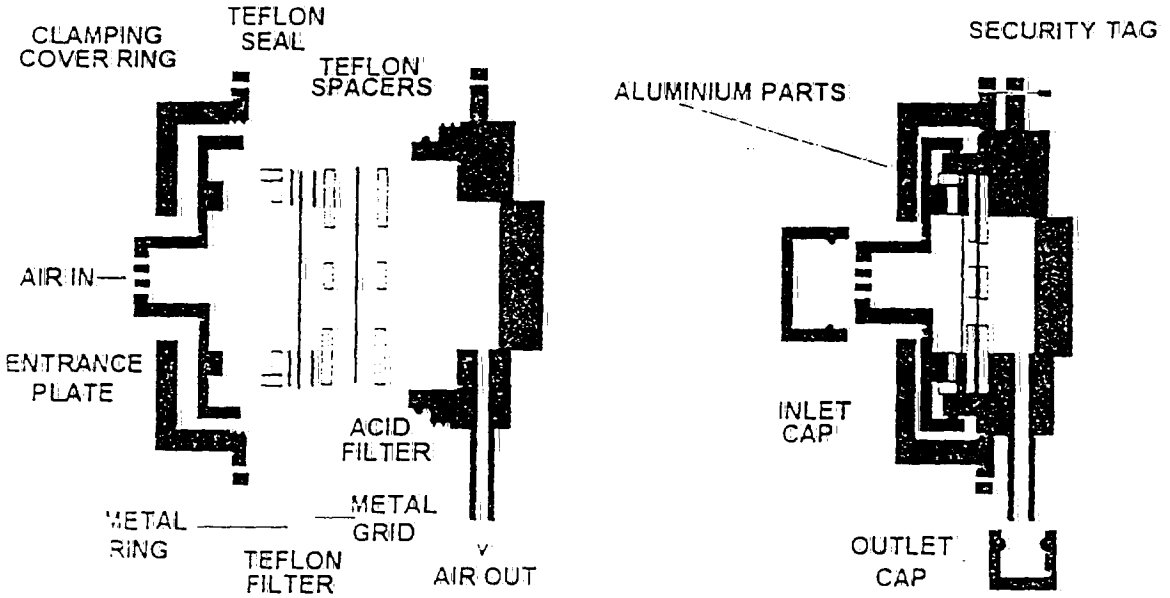
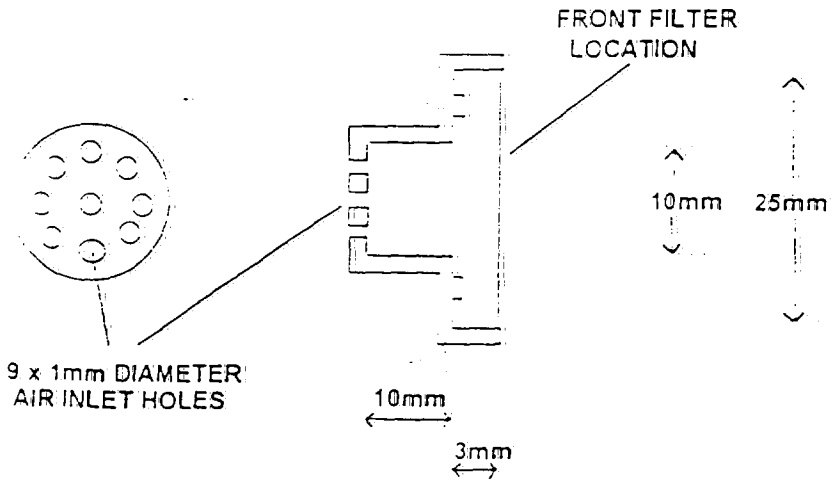
Figure 1

THE PERSONAL MONITOR FILTER HOLDER



FILTER HOLDER APART AND ASSEMBLED



ENTRANCE PLATE DIMENSIONS

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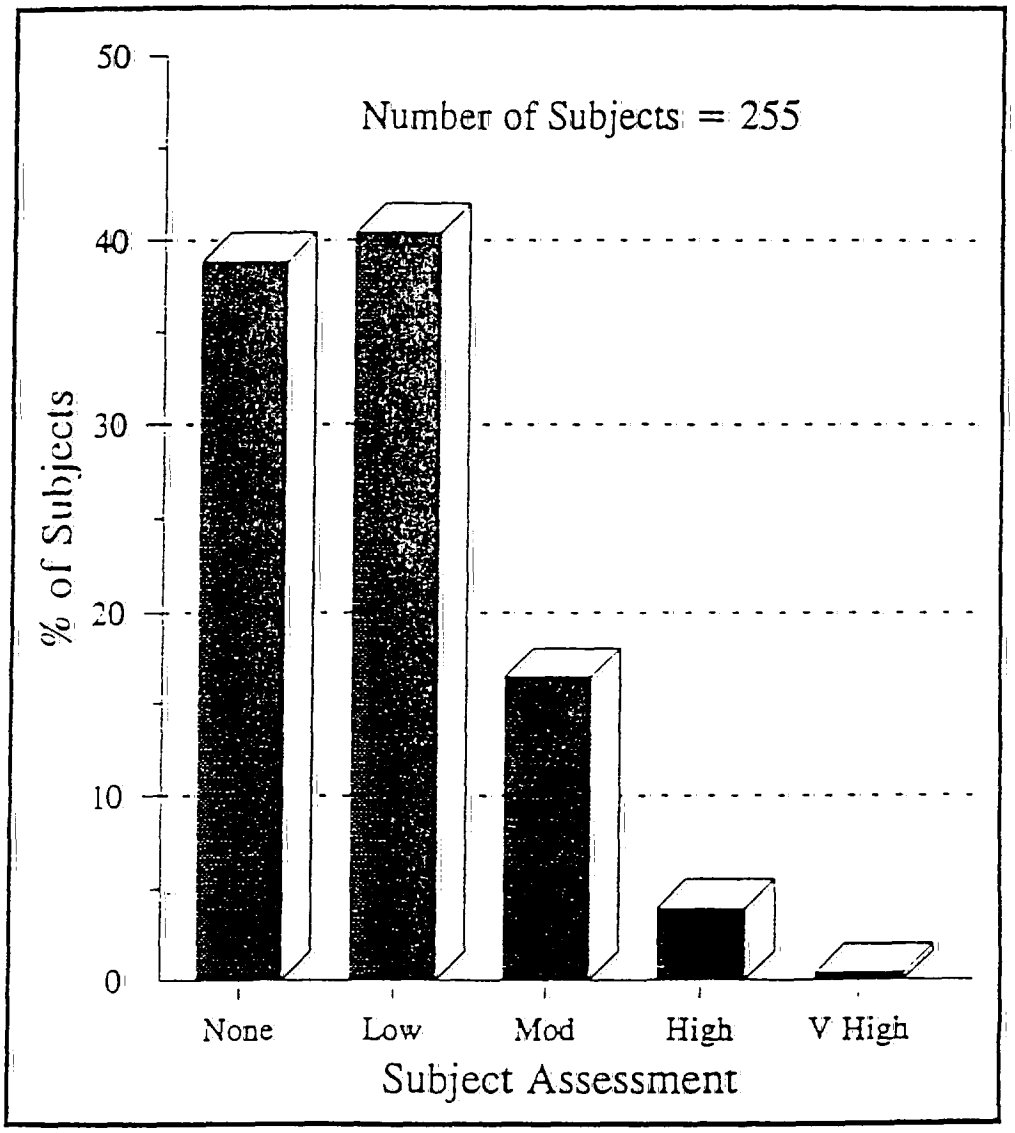
Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000

Figure 2

SUBJECTIVE ASSESSMENT OF 24 HOUR ETS EXPOSURE



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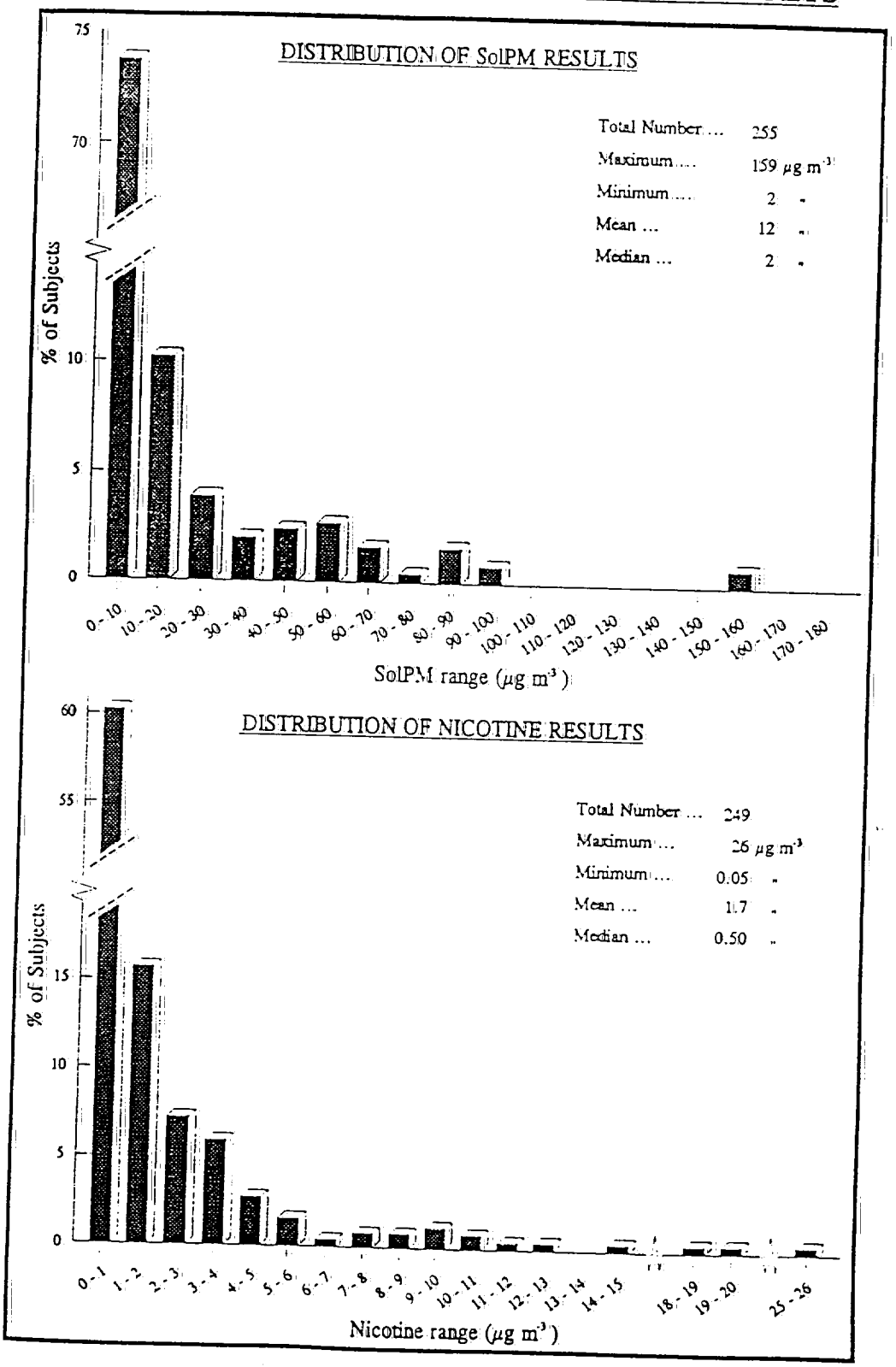
Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000

Figure 3

DISTRIBUTION OF SolPM and NICOTINE RESULTS



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Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000

Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000

Figure 4

DISTRIBUTION OF COTININE RESULTS

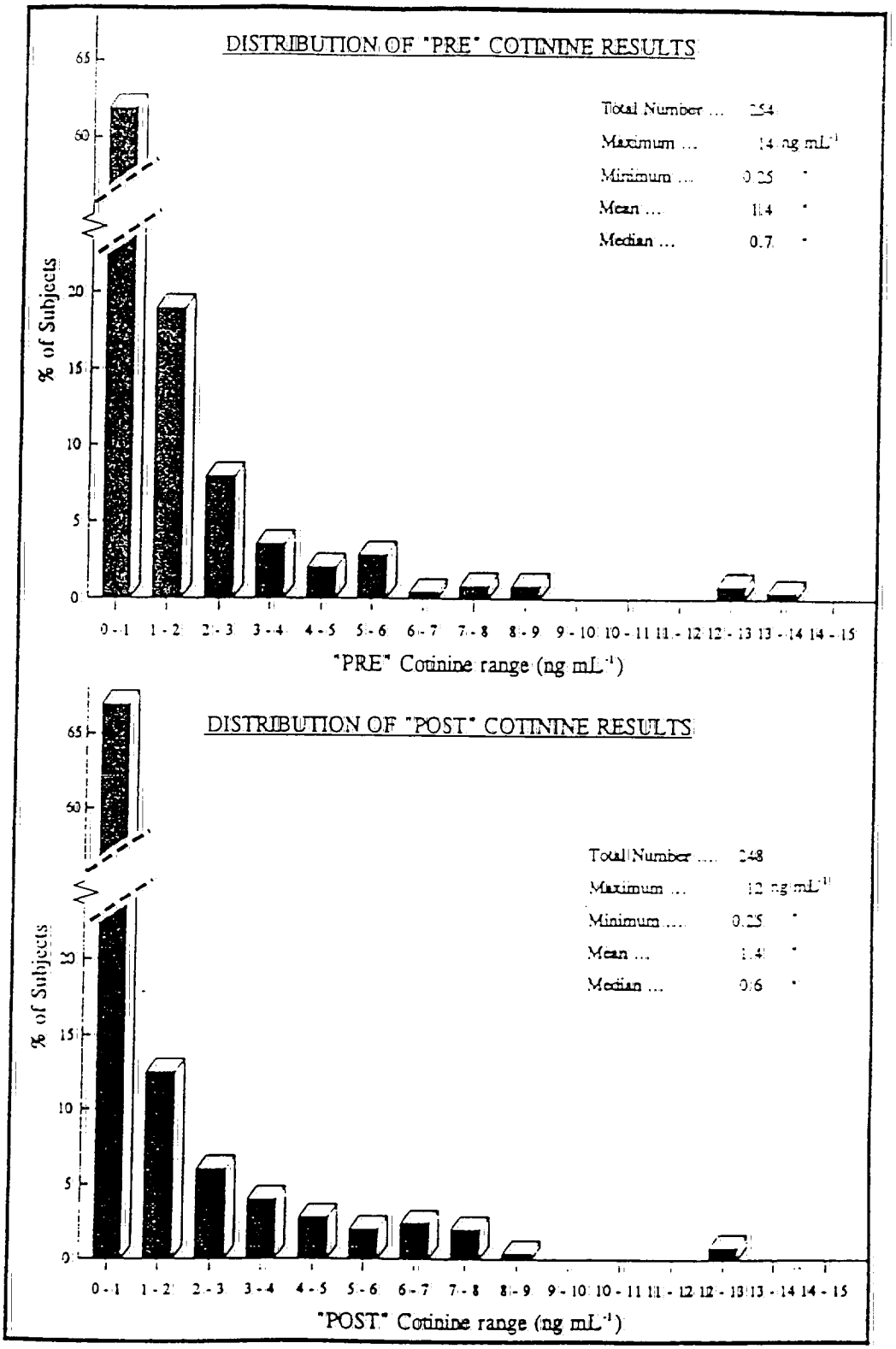

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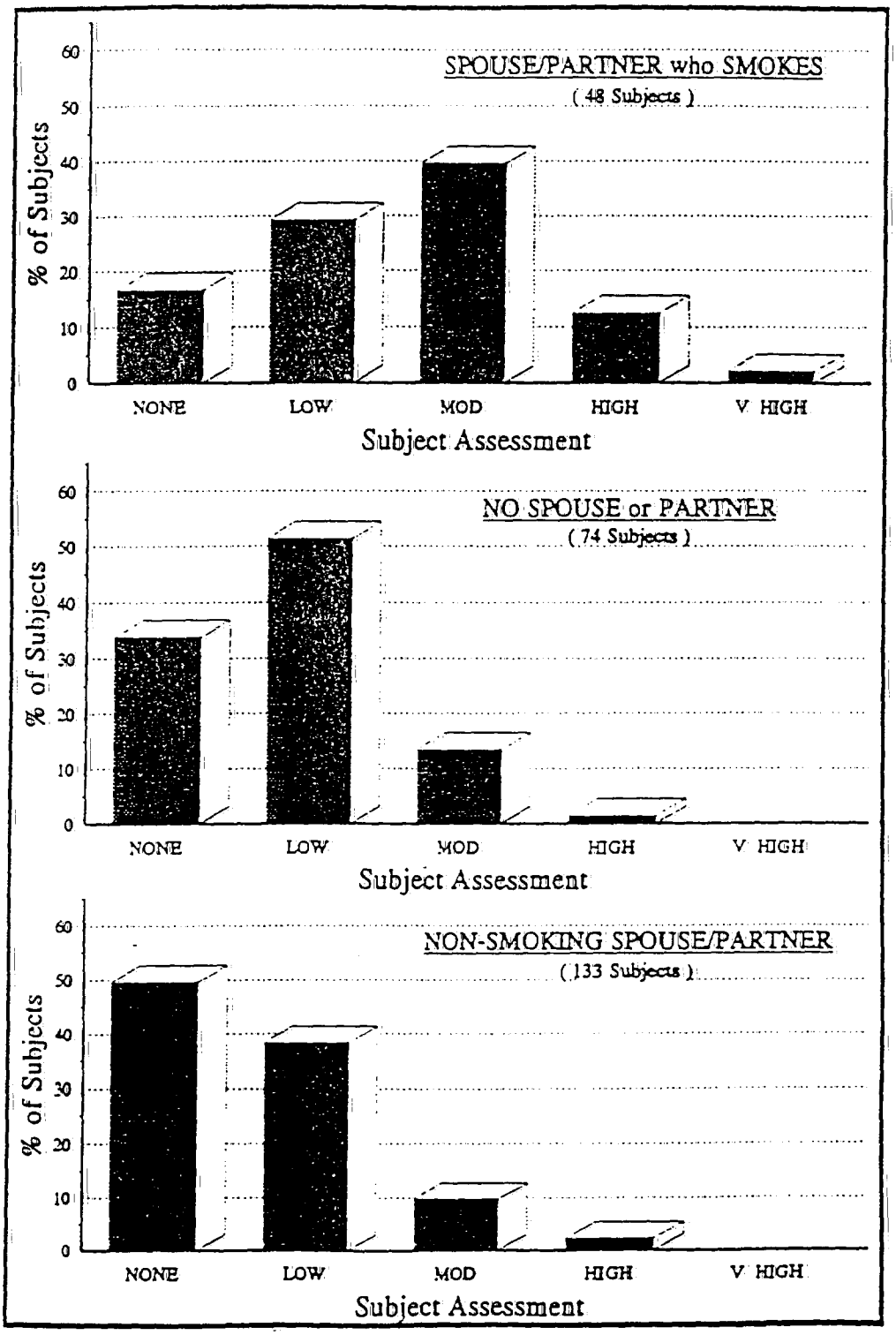
Figure 5

SUBJECTIVE ASSESSMENT OF 24 HOUR ETS EXPOSURE BY CLASSIFICATION OF SPOUSE OR PARTNER



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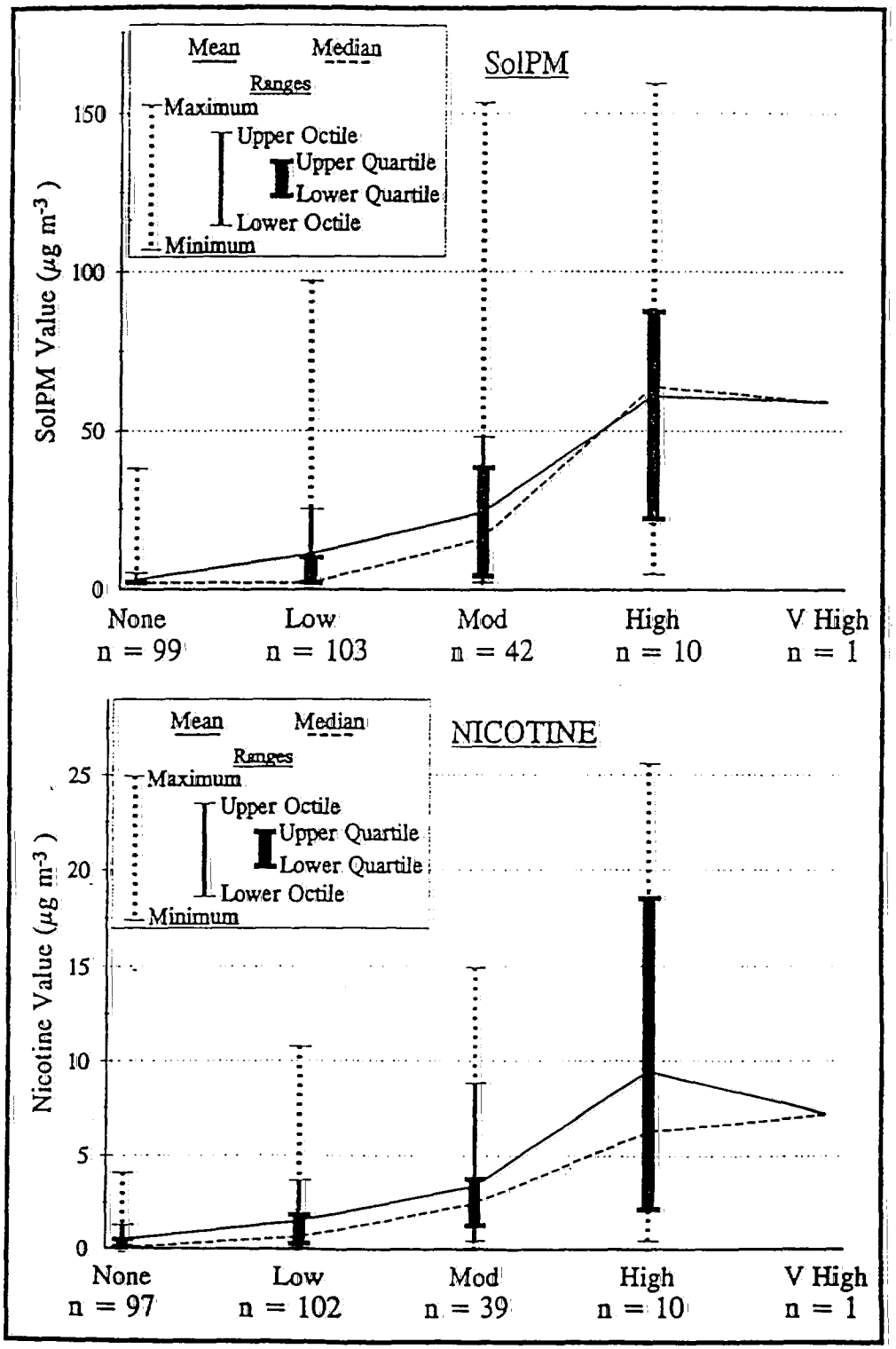
Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000

Figure 7

COMPARISON OF SolPM and NICOTINE RESULTS WITH SUBJECTIVE ASSESSMENT OF ETS EXPOSURE



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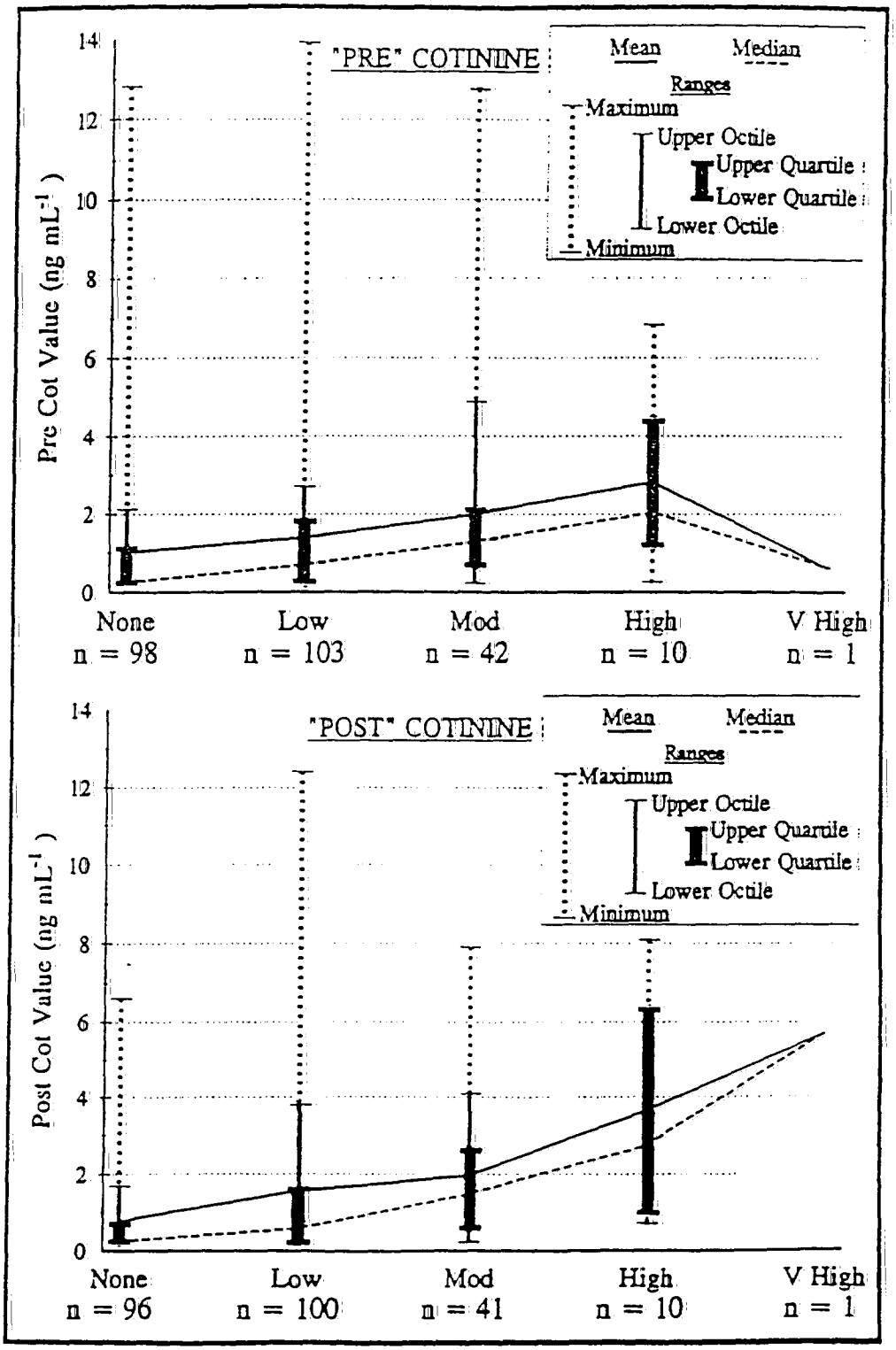
Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000

Figure 8

COMPARISON OF COTININE RESULTS WITH SUBJECTIVE ASSESSMENT OF ETS EXPOSURE



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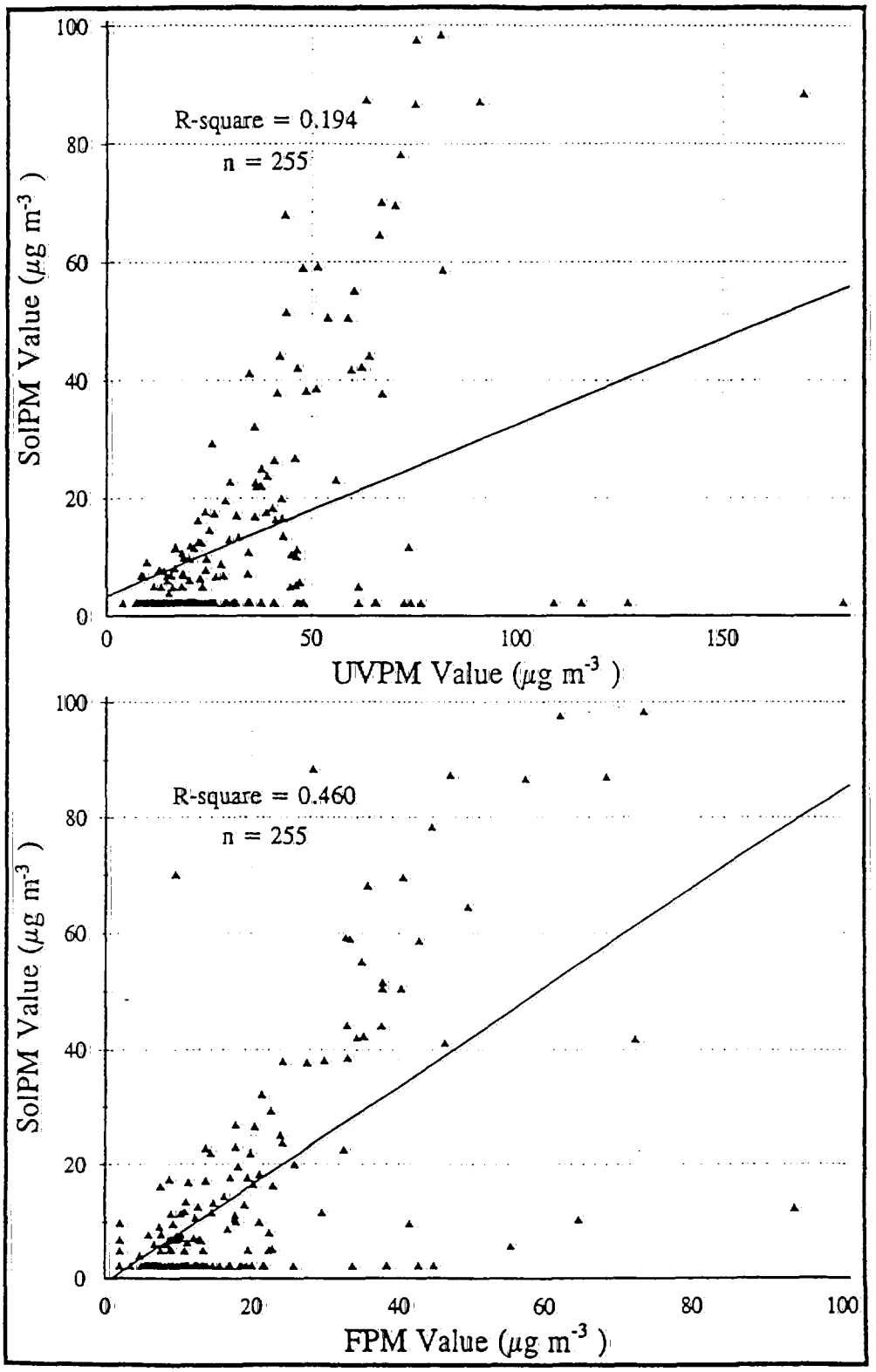
Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000

Figure 9

CORRELATION OF SolPM RESULTS WITH UVPM and FPM



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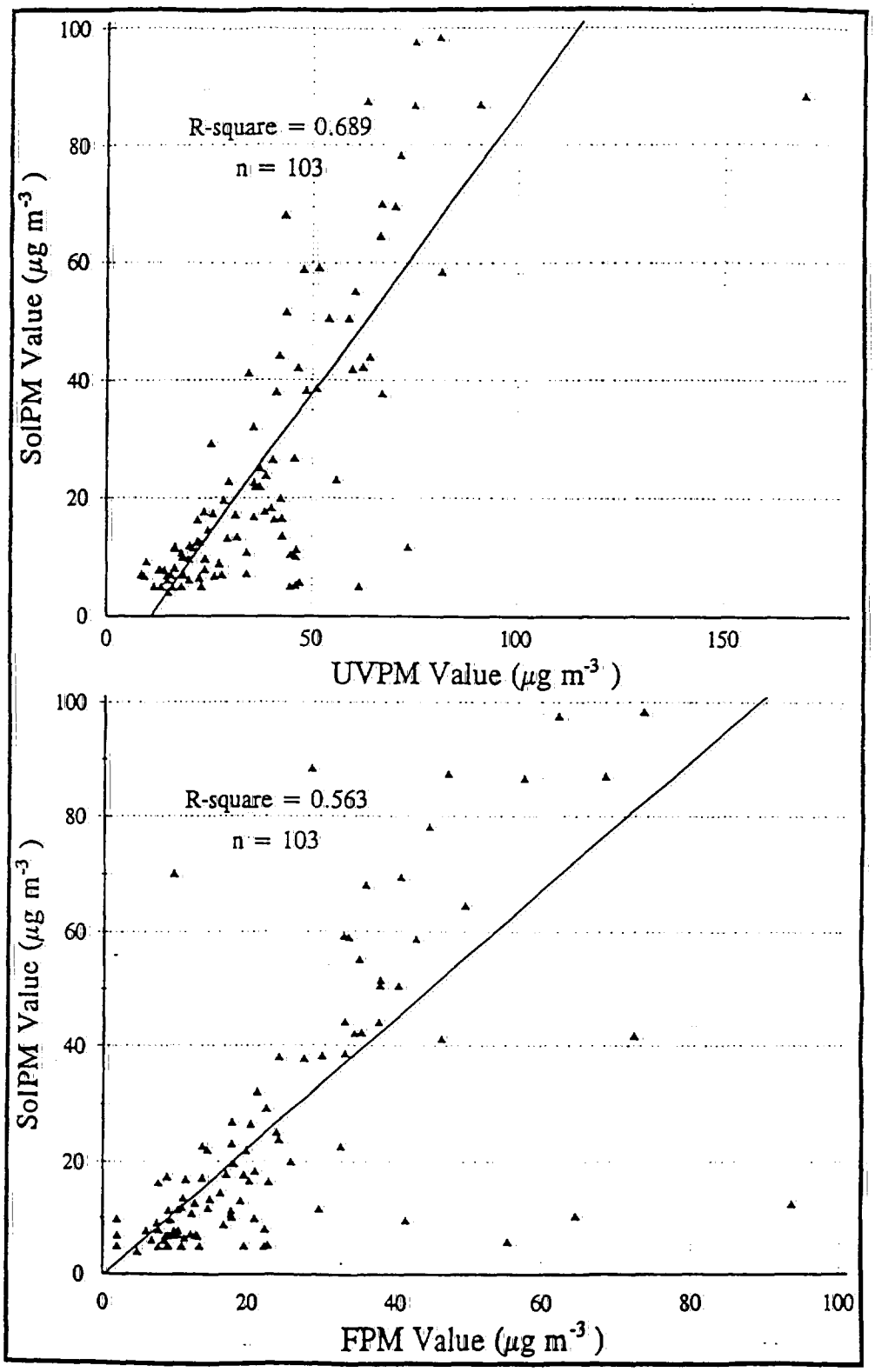
Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000

Figure 10

CORRELATION OF SolPM RESULTS WITH UVPM and FPM

after removal of SolPM = 2.0 $\mu g\ m^{-3}$



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Source: https://www.industrydocuments.ucsf.edu/docs/rfnm0000